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# NUMBERING OF NEW ELEMENTS FOR NET REFINEMENT

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Translation of "NUMERIERUNG DER NEUEN ELEMENTE BEI NETZVERFEINERUNG", Z., Angew Math. Mech. 68, 1988, 5, pp T399-T400



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Most methods from the area of adaptive net refinement are so designed that they can be implemented as post processors. This then opens new possibilities of operating net refinement methods controlled by error indicators in conjunction with existing finite element software.

The determination of the suitable numbering of the net can either be done with an optimization program, which is placed between the net refinement unit and the FE program, or it can be done in parallel with the refinement program. The first of these two alternatives operates on a complete net and the algorithms used are given the name "global". In the second alternative, only the old net is known as well as which elements are to be refined. These programs only use information from the immediate vicinity of each element and therefore will be described by the adjective "local".

The conventional global optimization algorithms are based on the ideas of Cuthill and McKee on the minimization of the bandwidth of a matrix. If the element numbers have to be determined again, then one uses the elements directly, or first the nodes are numbered again and the elements are numbered based on the nodes. The central idea of the method of Cuthill and McKee is to build up layers of adjacent elements.

As a rule, several passes with various starting elements are required in order to obtain a good result. This increases the complexity of global algorithms considerably.

Consequences regarding the layer concept:

i) The region of already numbered elements is continuous.

*Numbers in margin indicate foreign pagination.

ii) When one hits the edge, the layers decompose into several continuous components.

iii) Regions with relatively small element size lead to the deformation of the front.

From the planned method of operation of the local algorithm, it is found that a numbering in layers is not possible. Based on the procedure of network refinement units, we use a method oriented towards the elements:

i) The new elements which replace an old one, are inserted at the location of the old element. /400

ii) The relative numbering of the new elements is determined by a local minimization strategy as wide as the front.

iii) For a small number of special situations, the numbering obtained is changed and is adapted accordingly.

Consequences:

a) Only those elements require an effort which are to be refined.

b) No additional division of regions before or behind the front are produced.

c) If the numbering of the initial net separates expected singularities, then all of the nets retain this property.

In order to analyze both methods, the following restrictions are made:

- two-dimensional nets
- all nodes have the same number of degrees of freedom
- only one element type

For nonuniform refinement, we can conclude that

$$F = \frac{1}{h} cO(1) = E^{1/2} \cdot c \cdot 0(1),$$

F: = front width, E: = number of elements, h: = element diameter, c is a constant.

From the characteristics of the local diagram, we can conclude that the produced numbering of the growth law (1) is achieved. Based on the specified direction of travel through the structures, the proportionality factor in (1) in the local pattern can be much smaller for certain geometries than for global schemes with layer concept.

With a uniform refinement, in the least favorable case we can have:

$$F = E \cdot c \cdot 0(1).$$

This extreme case occurs if one refines exclusively around a single point. In this case, a global scheme can reach the growth law (1) by a suitable selection of the starting element in the center of the refinement. On the other hand, the automated search of such an element does represent a problem.

On the other hand, the local scheme can isolate singularities which is very difficult for a global scheme. This can lead to significant improvement of the front course.

By restricting ones self to locally available information, the additional complexity in the implementation of the local scheme can be made small.

Test runs with a series of different problems and various initial nets resulted in the following:

i) An infinitesimally small increase in the CPU time of the net refinement unit due to the local numbering scheme,

ii) confirmation of the theoretical results,

iii) in the initial nets matched to the problem, the local scheme gave the better element numbering,

iv) the global scheme required a high number of tests in order to find a suitable starting element.

The balance sheet is that a local numbering scheme represents an attractive alternative to global numbering algorithms.

## REFERENCES

1 AKIN, J. E.; PARDUE, R. M., Element resequencing for frontal solutions, in: WHITEMANN, J. R. (ed.), The Mathematics of Finite Elements and Applications II, Academic Press 1976, pp. 535–541.

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16. Abstract

This paper discusses new possibilities of operating net refinement methods that are open, including how determination of suitable numbering of the net is made.



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